Project Report

AI-Based Connect Four Game Using Minimax Algorithm

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Course: AI

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1. Executive Summary

Project Overview:

This project focuses on developing an AI-powered version of the classic Connect Four game. The main objective was to design and implement an AI opponent using the Minimax algorithm with Alpha-Beta Pruning, capable of making optimal decisions in real-time. The AI competes against a human player in a 7x6 grid setting, making strategic moves to win or block the opponent effectively.

2. Introduction

Background:

Connect Four is a two-player board game where players alternately drop colored discs into a vertical grid, aiming to align four of their discs horizontally, vertically, or diagonally. It was chosen due to its structured strategy and suitability for Minimax-based decision making. Our implementation uses a visual GUI created with Pygame to enhance user interaction.

Objectives of the Project:

Develop a playable version of Connect Four with AI functionality.

Implement Minimax algorithm with Alpha-Beta Pruning for optimal decision-making.

Test the AI's performance against a human player.

3. Game Description

Original Game Rules:

Players take turns dropping a disc from the top into one of the seven columns.

A disc falls straight down and occupies the next available space within the column.

The first player to form a horizontal, vertical, or diagonal line of four discs wins.

Innovations and Modifications:

Integration of a single-player mode against an AI.

Use of Minimax algorithm with Alpha-Beta Pruning to simulate strategic thinking.

GUI-based gameplay using the Pygame library.

4. AI Approach and Methodology

AI Techniques Used:

Minimax algorithm with Alpha-Beta Pruning was implemented to minimize the computation time while evaluating the game tree for optimal decisions.

Algorithm and Heuristic Design:

The heuristic evaluation function scores board states based on potential winning lines for the AI and the opponent.

A scoring window of 4 consecutive cells is analyzed across horizontal, vertical, and both diagonal directions.

Factors such as center column preference, three-in-a-row with empty cells, and blocking opponent's three-in-a-row are considered.

AI Performance Evaluation:

The AI was tested for decision accuracy, response time (~2 seconds), and win rate (~70% in typical test games against average human players).

5. Game Mechanics and Rules

Modified Game Rules:

Standard rules of Connect Four were retained.

One human player vs. one AI-controlled player.

AI makes a move using the Minimax algorithm with depth=5 and pruning optimizations.

Turn-based Mechanics:

Players take alternate turns. Human interacts via mouse clicks, and AI responds programmatically.

Winning Conditions:

A player wins if they align four pieces in any straight line (horizontal, vertical, diagonal).

If the board is full and no winner is found, the game ends in a draw.

6. Implementation and Development

Development Process:

Started by building the basic board logic and user interface using Pygame.

Integrated AI decision-making through the Minimax algorithm with Alpha-Beta Pruning.

Added win-checking, scoring functions, and board evaluation logic.

Programming Languages and Tools:

Programming Language: Python

Libraries: Pygame, NumPy

Tools: GitHub (for version control)

Challenges Encountered:

Optimizing the decision-making speed of the AI with deeper Minimax trees.

Designing a heuristic function that balances offense and defense.

Ensuring the AI's responses are consistent and strategic across all game stages.

8. Results and Discussion

AI Performance:

Win Rate: Approximately 70% in test games against human players.

Average Decision Time: ~2 seconds per move at depth=5.

Effectiveness: The AI successfully blocked human win paths and prioritized winning strategies,

showcasing intelligent behavior under constrained time.

9. References

Alpha-Beta Pruning and Minimax Algorithm Tutorials from GeeksforGeeks and YouTube.